SIMULATION OF CONSOLIDATION AND TRANSPORT PROCESSES IN CLAYEY ROCKS

Maxim G. Khramchenkov, Kazan State University, Russia

Abstract: A united mathematical model for the rheological and transport properties of saturated clays is proposed. The foundation of the model is the unification of filtration's consolidation theory and the theory of the stability of lyophobic colloids, which is based on the conception of 'disjoining' pressure as a surplus in relation to hydraulic pressure. This pressure is caused by surface capacities and exists in water films between clay particles. In this work it is shown that the problem of the shrinkage of a clay layer can be reduced to the well known problem. We obtained the approximate solution for pressing the water out of a clay layer. The solution that we obtained requires introduction of a concept for the limit shear stress for clays. We investigated the model, and explained some characteristic features of transfer processes in clays (the existence of anomalous high pressures in clays, the flocculation at diffusion in clays, etc.). It is shown that solutions which we received are in harmony with results of experiments.

1. INTRODUCTION

Properties of clays and clayey rocks, and also the processes in them depend on a number of factors. Then the mathematical simulation of the properties and processes, as one of the methods of their examination, is a rather difficult problem. Physically it is clear that the specific properties of clay rocks (low permeability, plasticity in moist condition) are caused by the existence of clay minerals in their composition, and these properties are a manifestation of surface capacities, which exist between particles of the clay minerals, which are included in the composition of clays. The most useful conception of the activity of surface capacities is the conception of disjoining pressure between colloid particles, Mitchell (1976). In this work we provide a description of the physical and mechanical clay properties and transport processes in them. The description is based on methods of theory of filtration consolidation, Nikolaevskiy (1996), and also on the theory of stability of lyophobic colloids (theory of Derjaguin-Landau-Verwey-Overbeeck, or DLVO theory), which uses the conception of disjoining pressure.

2. MECHANICS OF CLAYS AND CLAYEY ROCKS

The specific properties of clay rocks (low permeability, plasticity in moist condition) are caused by the existence of clay minerals in their composition. Clay minerals are hydroalumosilicates of calcium, magnesium, potassium and natrium and they are structurally arranged as thin sheet particles (about 50- 100 nm in diameter and a few nm in height). Because of the isomorphic replacement in the crystal matrix these particles usually carry an electrical charge (usually negative), which is compensated by cations. Cations are adsorbed on to the surface of particles and at hydration they are able to dissociate (totally or partly) and make the double diffusion layer, Mitchell (1976). Before we proceed to theoretical examination of clay properties, we describe the structure of clay rocks. We will consider clay rocks as a solid porous skeleton (not essentially coherent), which pores are not fully filled by clay particles. In that case any process, connected with the deformation of clay rocks, could be divided into two stages: 1) free porosity (part of pore volume, which is not filled by clay particles and their interlayer intervals) is not equal zero; 2) free porosity is equal to zero, it means that all pores are filled by clay particles and interlayer films of water. We begin examination from the first stage. We will consider that the filtration is going only in the free part of the pores. Now we can write mass balance equations for liquid and solid phases:

$$\frac{\partial(m_{p,c}\rho_f)}{\partial t}+\mathrm{div}(\rho_f m_{p,c}\vec{V_f})\pm j=0, \qquad (1)$$

$$\frac{\partial\left[(1-m_p-m_c)\rho_s\right]}{\partial t}+\mathrm{div}[\rho_s(1-m_p-m_c)\vec{V_s}]=0 \qquad (2)$$

In these equations ρ_f is the density of fluid (water), ρ_s - density of solid phase, $\vec{V_f}$ - fluid velocity in transport pores, $\vec{V_c}$ – fluid velocity between clay particles, $\vec{V_s}$ - solid phase velocity,